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JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

Volume XVIII MAY, 1931 Number 5

PLANNING BOSTON'S THOROUGHFARES

By Frederic H. Fay *

(Presented at a meeting of the Boston Society of Civil Engineers, February 18, 1931)

Mr. President, Members of the Boston Society of Civil Engineers, and Guests: It is certainly a pleasure to be with you tonight and see such a wonderfully fine turnout — far greater than the weather would seem to warrant.

As to the thoroughfare plan for Boston. Boston is suffering from arteriosclerosis, — a hardening of its transportation arteries, with consequent high traffic pressure and resulting deterioration in certain parts of the downtown business district. A major operation is necessary to effect a cure. New arteries must be opened up and existing arteries improved to relieve the pressure on present overburdened arteries, to establish a normal circulation of traffic, to arrest decay, and to insure future healthy municipal growth.

Boston Traffic Conditions

There is probably no city in the United States where traffic conditions on the streets of the downtown business section are so near the saturation point as they are here in Boston. In fact, our traffic has been at the saturation point for the last four or five years. That has been demonstrated several times, as you will recall, when from seemingly slight causes traffic on certain occasions has been absolutely paralyzed and could not move for considerable periods on the downtown streets.

---

* Of Fay, Spofford & Thorndike, Boston, Mass. Chairman, City Planning Board of Boston.

Street Areas in Cities

The street area in the business sections of certain American cities was studied by Prof. Miller McClintock of Harvard, the results being given in his admirable report on the Boston Traffic Survey. In that report he lists fifteen representative cities, and gives the proportionate area of central business districts devoted to roadways, that is, to the space between curb lines used by vehicles.

In the city of Washington we find a maximum space devoted to roadway area in the central business section, that city leading with 44 per cent. Cleveland, for example, has 39.5 per cent of its downtown business section given over to roadway area; St. Louis has 37 per cent; Chicago, 29 per cent; and out of the list of fifteen cities Boston is No. 13, with 25 per cent of the area of the principal business district devoted to roadway use. Only Toledo, with 24 per cent, and Los Angeles, with 21.5 per cent, trail behind Boston. Here in Boston we have a roadway area of 25 per cent, sidewalk area, 12.6 per cent, or a total of 37.6 per cent of the downtown district given over to highway uses for both vehicles and pedestrians.

Boston has an unusually large number of streets, many of them laid out more than two centuries ago to meet the needs of the village and the small town. Boston would be far better off if in the downtown district we had one-half as many streets and each of those streets was twice as wide. In that case we would have no such problem of traffic congestion as we have at the present time. In other words, Boston has too many streets and the streets are only half wide enough.

Effect of Traffic Congestion on Real Estate

The effect of traffic congestion is reflected on the real estate abutting on these narrow, congested streets, the use to which that abutting property can be put, and the demand for such property. Evidence that the point of saturation in street traffic of Boston was reached about five years ago is found in the valuation of the downtown district, now Ward 3. While from 1925 to 1930 the total valuation of Boston increased from $1,862,000,000 to $1,972,000,000 (an increase of $110,000,000), in Ward 3 the valuation actually decreased from $799,000,000 to $765,000,000 in that five-year period. This shrinkage has taken place notwithstanding the fact that in certain sections many new buildings, such as the United Shoe Machinery Building, the Tower Building, the North Station group and the Atlantic National Bank, have been built with a valuation in excess of $30,000,000. In a very considerable part of the downtown area, not only in the market district but immediately southeast of the retail trade section, block after block has been shrinking in value, primarily because of the congestion and the resulting cost of doing business in the downtown district.

Monetary Loss Due to Traffic Congestion

Congestion is costly, and various bodies which have been investigating traffic conditions in other cities as well as in Boston have attempted to evaluate the monetary loss due to traffic delay. The Regional Survey in New York estimates the cost of congestion on Manhattan Island at $500,000 per day, and for the whole of the greater New York region at $1,000,000 per day, due to the slowing up of traffic; $1,000,000 per day is equivalent to 5 per cent on a capital investment of $7,300,000,000.

Here in Boston, the American Road Builders Association estimated a traffic loss of $81,000 per day, which would be 5 per cent on a capital investment of $591,000,000. These figures are more than merely guesswork; they are reasonable approximations based on certain facts. We know that here in Boston trucking is extremely expensive. We have estimates from various truckmen that their trucks lose from one to three hours per day, mainly due to traffic delays. There are 13,000 trucks registered in Boston city proper. Assuming that these 13,000 trucks are seeking to move over our streets every day (while all those registered in the city are not moving in the downtown district there are vast numbers from outside which are coming into Boston), — assuming that the 13,000 are attempting to do business in the downtown district, and that the cost of operating a truck, including the driver's compensation, is 5 cents per minute, or $3 per hour, that one item alone amounts to over $19,000 per day, or $6,000,000 per year, if the delay is only one-half hour per truck on the average. If the trucks lose an hour a day that means a loss of $12,000,000 per year.

This traffic congestion and the resultant delay do not mean a loss solely to truckmen and expressmen attempting to move vehicles through these downtown streets; it also affects merchants, manufacturers, industries, every one all through the suburbs and throughout the Metropolitan District, all who seek to do business in Boston and to reach the railroad terminals and steamship piers.

Boston's Expenditures for Street Improvements

What has Boston done, and what is it doing, in comparison with other cities, in the way of spending money on street improvements? Since Boston became a city in 1822 the sum of $70,000,000 has been spent on street improvements, but in the last ten-year period beginning with 1920 improvements were authorized to the extent of $46,000,000, or, on the average, $4,600,000 per year. That, of course, is a substantial sum. Chicago, however, has authorized in the last twenty years planning projects amounting to $300,000,000. St. Louis, in 1923, passed by referendum vote a bond issue of $87,000,000 for a ten-year program of street improvements. Detroit proposes to spend $340,000,000 on superhighways in addition to $200,000,000 on rapid transit lines. Dallas, Texas, with a population of 260,000, one-third the size of Boston, recently authorized, by referendum vote, the funds for a nine-year program of street improvements which calls for an expenditure of $4,000,000 per year.

Street improvements, wisely made, bring many and far-reaching benefits. The first is cheaper transportation and the lessened cost of distribution of goods. This may be reflected in the cost of living, because distribution is the largest factor in getting goods from the producer to the consumer. But beyond that, wisely planned street improvements further real estate development and increase property values. Take as an example the Michigan Avenue improvement in Chicago. Years ago, when Michigan Avenue reached the Chicago River at its northerly end, the passage over that river was by a narrow, decrepit bridge known as the Rush Street bridge. The city decided to widen Michigan Avenue and to carry the new boulevard across the Chicago River by a magnificent new bridge of great width, thus connecting with the district to the north. The Michigan Avenue improvement cost Chicago $16,000,000. It was directly responsible, however, for over $100,000,000 increased property values. The tax revenues from $100,000,000 worth of new property are about three times the carrying charges to the city of that improvement. In other words, Chicago is actually making money and getting good return in taxes.

Study of Traffic Situation in Boston

Some four years ago the Boston City Planning Board began a comprehensive study of the traffic situation in Boston and the need of street improvements. The traffic investigation was the second step in a comprehensive plan for this city, the first having been the preparation of the zoning measure adopted in 1924.

In carrying out the investigations in Boston we first of all selected the best diagnostician for our ills that we could find, — Mr. Robert Whitten, now president of the American City Planning Institute, under whose intensive personal direction all the work has been done. Fortunately, during our investigations, we were able to secure the heartiest co-operation of the Metropolitan Planning Division, which also retained Mr. Whitten to carry investigations out into the Metropolitan District in so far as the plans proposed for the city of Boston related to conditions beyond the city limits.

TRAFFIC COUNTS

In carrying out this study we were able to work from unusually complete factual data. Thanks to Prof. Miller McClintock, who carried out the admirable traffic survey of 1927; to the Boston Chamber of Commerce, which had from time to time taken traffic counts throughout the city; and to the traffic investigations of the Planning Board itself and of the Metropolitan Planning Division, Boston had, for the first time, practically complete data as a basis on which to work. These data not only included ample statistics of the traffic moving past any given point in a given period of time, — that is, the volume of traffic, — but throughout the Metropolitan District very complete records were obtained of the origin, the routing and the destination of traffic; that is, the drivers of cars were stopped all over the district and asked where they came from, what route they were following, and where they were going. More than that, full records were obtained as to the average speed of movement from the heart of Boston outward into the Metropolitan District in all directions, so as to determine how fast one could travel to the west, south, north or northeast. There is probably no city in the world today, — and by city I refer now to the metropolitan city, — that has such complete information as to the movement of the traffic within its borders as we have right here in metropolitan Boston. It was on the basis of those facts that Mr. Whitten, for the Planning Board, has been able to plan, we believe, most wisely, and to demonstrate the economic worth of each project which has been recommended. By "economic worth" I mean that he can show how much traffic a given new route is likely to carry today, in 1935, or perhaps thirty or forty years hence, and how much time each vehicle moving over that route would save; and by allowing a proper unit of cost for the movement of that vehicle, including the time of the driver, we can arrive at a reasonable estimate of the worth of the various proposed improvements. It was on such basis that the merits of each of the various projects under consideration were studied. Some projects were discarded, others adopted, and the result is the complete report which was issued last fall by the City Planning Board.

Thoroughfare Report

In the Thoroughfare Report there has been outlined for the first time a comprehensive program of the major street improvements to be carried out over a period of probably twenty-five years, perhaps longer, depending on the financial ability of the city to put through the program. Heretofore every street improvement in Boston — and that is true usually of cities generally — has been carried out on a hit or miss plan; that is, it has been considered solely by itself and without any broad consideration of its bearing upon the city as a whole and upon other street improvements which might come along later. Now, for the first time, Boston has a co-ordinated plan in which each particular project is a link in a complete chain. If the plan is carried out logically, step by step, in a few years' time we shall see a vast improvement — a vast speeding up of traffic in this city.

In that report, of which summary copies were distributed at this meeting, you will note we put down as the first project of major importance the building of the East Boston vehicular tunnel. That, fortunately, is authorized, and bids will be received for building the major portion of the tunnel, that is, the portion beneath Boston Harbor. The second major improvement recommended in the report is what is called the Central Artery, or a street extending through the heart of the city, cutting across the market district, and skirting the edges of the banking, office and retail districts, following a route where land values are not excessive. This Central Artery, with its extension to the southerly city limits by the proposed Blue Hills Radial, forms the backbone of the new system.

Central Artery

The Central Artery will start at Causeway Street opposite Nashua Street near the North Station. It will follow Portland Street, Merrimack Street and Haymarket Square; will cut through the heart of the market district, passing the entrance to the East Boston Tunnel, and then will skirt the financial and retail districts to Albany Street and the

South Bay section of the city. This Central Artery will be, when fully complete, a street unique for Boston; that is, it will be a two-level street. New York had to come to Boston in the late 90's to learn how to build subways for the accommodation of street railway traffic, as Boston was the pioneer in that field. New York, however, has shown Boston the way to build a double-deck street. Already there is in operation on the West Side of New York, along the westerly water front, a double-deck street built for a distance of one and one-half miles from Canal Street to West 23d Street, and about to be extended two and one-half miles farther to 72d Street, where it will link up with Riverside Drive. A few weeks ago, while in New York, the speaker took particular pains to investigate that double-deck street, which then had only recently been opened, driving back and forth on the upper level and on the surface street beneath. On the upper level the three-mile round trip, including a delay in traffic at the turn at Canal Street, was made by taxi in less than six minutes. On the upper level vehicles can readily travel at speeds of thirty to forty miles an hour.

Upper Level for Central Artery

The upper level street of the Boston Central Artery will be 60 feet wide and will provide for three lanes of traffic moving in each direction. The surface of the upper level street will be about 20 feet above the surface of the main highway. The width of 60 feet allows ample space between the side of the upper level street and the buildings abutting on the main thoroughfare. The upper level street, as proposed, by no means cuts off light or air from abutting property. If one goes to New York and sees what has been done by a street of the same size as that proposed for Boston, he will be surprised to find how adequate and how light is the surface roadway beneath the upper level structure. Vehicles traversing the upper level street are passing over a smooth, unbroken pavement, and make far less noise than do vehicles on the surface which are crossing loose manhole covers, getting into ruts and putting on their brakes to avoid running into other vehicles. In other words, traffic on the upper level moves with a fraction of the noise made by traffic on the surface.

In Boston the upper level street will start near the North Station and will extend through the business district as far as the Dover Street bridge at Albany Street, a two-mile stretch over which traffic can move at any reasonable speed, thirty to forty miles an hour or more. Because there will be no cross traffic there will be no occasion to slow down. As ramps are provided at suitable intervals from the upper to the lower level, traffic can enter the business district at various points, or can move rapidly through the city.

It is estimated that the building of the Central Artery, with its upper level street, will remove at least 40 per cent of the traffic now found on Tremont, Washington, Devonshire and other streets in the downtown section, today so heavily congested. Then the traffic legitimately using these streets will move at greatly enhanced speed.

Financial Program

As to the financial program for carrying out this plan, study of the full Thoroughfare Report will show that the expense for the next ten years need not be much larger than the rate of expenditure authorized for Boston's street improvements during the last ten years. Instead of proceeding on a hit or miss plan, by building to a co-ordinated program, in ten years' time one will see a marvelous change in traffic conditions in this city. During the next ten years traffic is expected to increase one-third above what it is today. Notwithstanding this increase, ten years hence it will be far easier to drive downtown, and the driving time between the business district and the suburbs will be decreased twenty-five to thirty-five per cent at least. It now requires about twenty minutes to drive from the Dover Street bridge to the North Station. By means of the Central Artery this time will be reduced to five minutes. From Arlington Square to Rowes Wharf now takes about fifteen minutes; this time will be cut to four minutes.

Projects to Benefit also Metropolitan Area

These projects are by no means solely of benefit to the city of Boston. They benefit every one who seeks to come into Boston and do business here, or who seeks to pass through Boston from one part of the Metropolitan District to another. In view of the fact that 60 per cent of the population of the metropolitan area is outside the city limits of Boston, and that a considerable proportion of that outside 60 per cent is concerned with doing business in the city, the benefits which will accrue from this program when carried out will be widely distributed and will affect the entire metropolitan area and will even benefit communities much farther out. For example, this fall or early winter shippers were trucking apples for export, from Shelburne Falls to Boston; even the Shelburne Falls truckmen will be benefited by this improvement in Boston's downtown section.

There is in the Legislature at the present time a bill for inaugurating the first step in this major program, House Bill No. 1259, which provides for the widening of Chardon Street and for building that portion of the Central Artery from Chardon and Merrimac streets past the East Boston Tunnel to State Street. The bill also provides for the widening of Albany Street between Kneeland Street and Broadway, and of Way, Motte and Castle streets to Arlington Square. This is the first step in the program, and one which we devoutly hope will pass this year's Legislature.

As said before, the complete thoroughfare program does not stop at the city line. Thanks to co-operation from the Metropolitan Planning Division and the State Department of Public Works, the plans proposed for Boston link up with projects for greatly improved transportation facilities throughout the entire metropolitan area. If this program be carried out, even in part, along the comprehensive and coordinated lines laid out, in ten years one will not recognize Boston for the speed and ease with which one can enter and do business in this city.

AN OUTLINE OF THE BOSTON THOROUGHFARE PLAN

By Robert Whitten *

(Presented at a meeting of the Boston Society of Civil Engineers, February 18, 1931)

The Thoroughfare Plan (Fig. 1) includes nine major projects, as follows:

1. *Central Artery.* — A new two-level street from Nashua Street to the northern terminus of proposed Blue Hills Radial at Kneeland and Albany streets.
2. *Blue Hills Radial.* — Express road from proposed Central Artery at Kneeland and Albany streets to Blue Hill Avenue at Seaver Street.
3. *North Shore Radial.* — Express road from proposed State highway in Revere along Boston & Maine Railroad and through Day Square to the East Boston Tunnel portal.
4. *Roxbury Crosstown.* — Express road from Old Colony Parkway north of Savin Hill to Bay State Road at Ashby Street.
5. *Charles River Parkway.* — Depressed roadway from Longfellow bridge along southerly side of Charles River to Cottage Farm bridge.
6. *North Beacon Street, Brighton.* — Express road from Union Square westerly to the Charles River.
7. *Canterbury and Clarendon Hills Parkways.* — Express road and parkway from southern terminus of proposed Blue Hills Radial at Seaver Street to proposed Neponset River Parkway, with a branch connection from Clarendon Hills to West Roxbury Parkway and Washington Street.
8. *Neponset River Parkway.* — Express road and parkway along Neponset River from Readville to Quincy Shore Drive, near Neponset bridge, with a branch to Southern Artery via Adams Street.
9. *Boston & Albany Highway.* — Elevated roadway over Boston & Albany tracks from Commonwealth Avenue at Cottage Farm bridge to Arlington Square.

The present thoroughfare layout is defective in its radial access to

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* City Planning Consultant, New York City.

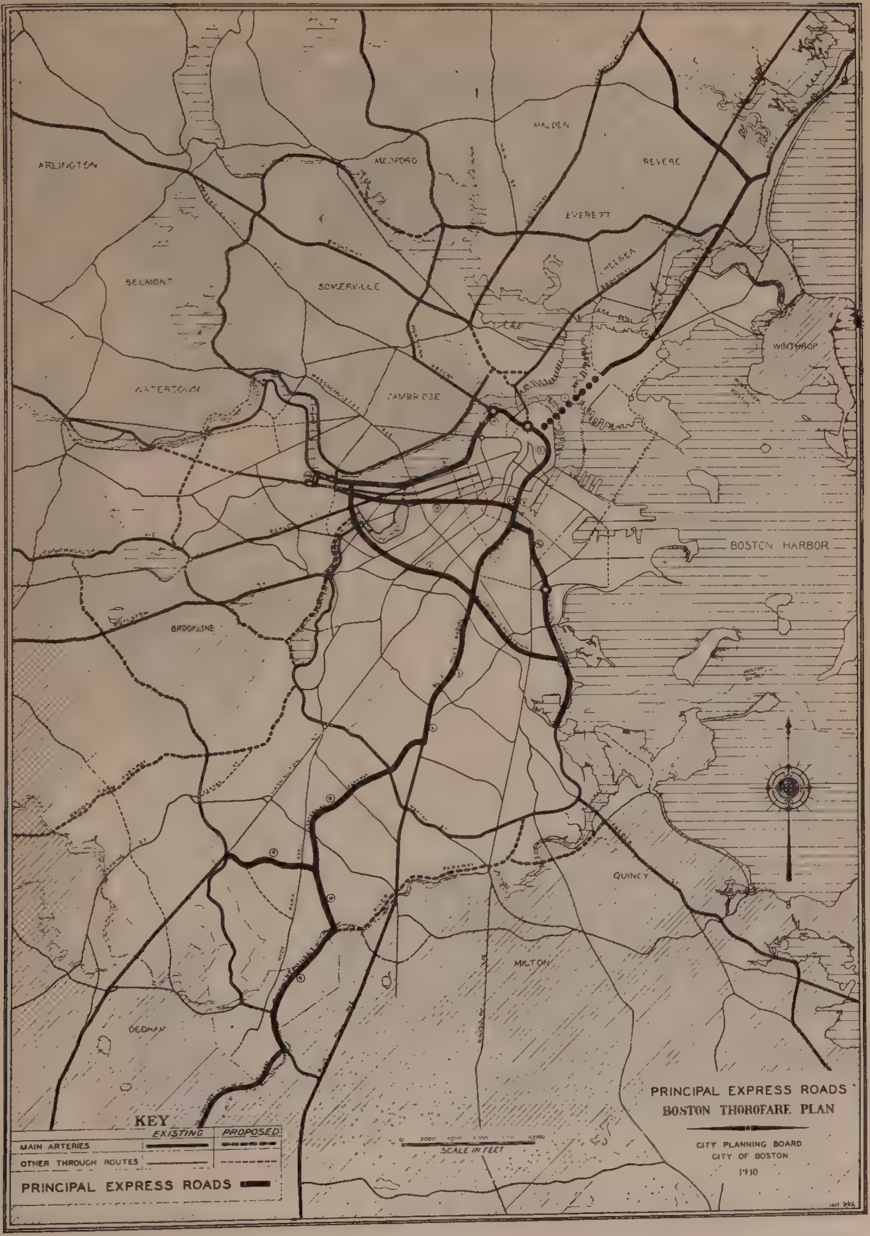


FIG. 1. — BOSTON THOROUGHFARE PLAN

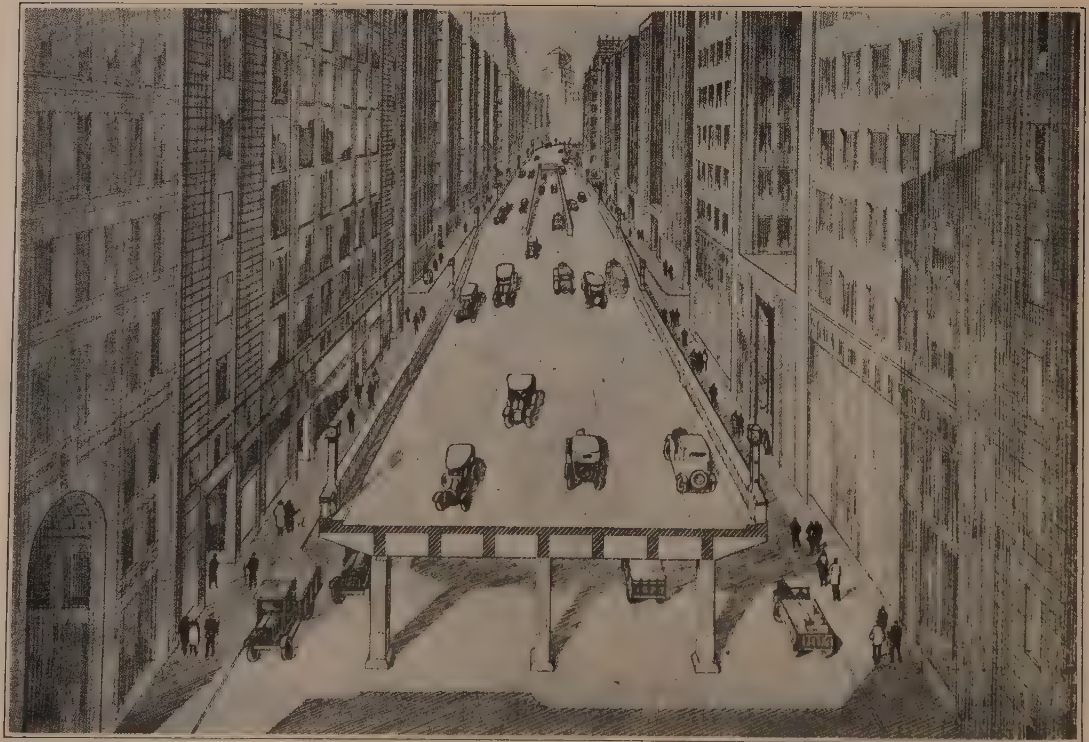


FIG. 2. — TYPICAL VIEW OF PROPOSED CENTRAL ARTERY SHOWING UPPER LEVEL ROADWAY

The upper level roadway is designed for six lanes of fast moving vehicles; the surface roadway for six lanes of slower moving vehicles, as well as space for vehicles standing at the curbs

Central Boston, both from the northeast and from the south (see Fig. 5). This is shown clearly by a careful timing of trips to and from Central Boston made by the mayor's Street Traffic Survey. In thirty minutes one can travel about twice as far to the west via Beacon Street, or to the northwest via the Northern Artery, as toward Chelsea, East Boston and the North Shore, and about one and three-fourths times as far as toward Roxbury, Dorchester and the south.

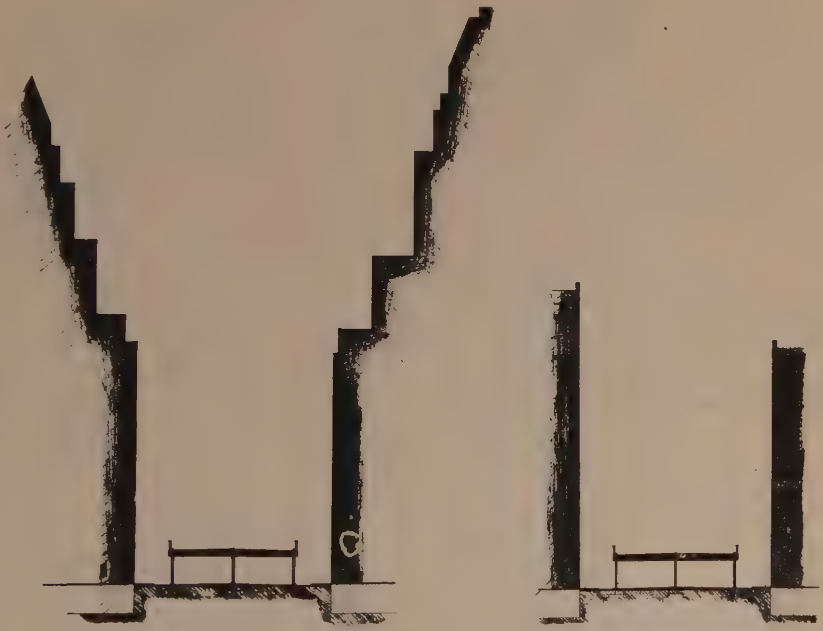


Fig. 3. — Cross-section of Elevated Roadway compared with Allowable Building Heights

North-South Express Road

A central feature of the Thoroughfare Plan (Fig. 1) is a great north-south express road extending from the northerly city line bordering Revere to the southerly city line at Readville, a distance of 13.7 miles. It will connect the State highway system serving Revere, Lynn, Salem, Beverly and other North Shore cities and towns on the north with the State highway system serving Stoughton, Taunton, Fall River, New Bedford and neighboring towns on the south. It will also connect with a proposed new highway to Providence. This route is made up of all or parts of six major projects:

The North Shore Radial.
The East Boston Tunnel or Bridge.
The Central Artery.
The Blue Hills Radial.
The Canterbury Parkway.
The Neponset River Parkway.

This north-south express road will greatly facilitate access to Central Boston, both from the northeast and from the south, and will also furnish a quick and direct route from Chelsea and East Boston on the north to Roxbury, Dorchester, Hyde Park and Milton on the south. Over this whole course of over thirteen miles an automobile will be able to maintain an average speed of about thirty miles an hour. This is about two and one-half times the present average speed. All of the outlying areas, both north and south, will be brought appreciably nearer in point of travel time to Boston proper. This will tend both to build up the outlying areas and to increase business in the central areas. It will also mean an enormous economic saving to the motor vehicle users, and a material reduction in the cost of transporting goods and of carrying on business and industrial operations.

Connections of Express Road with Other Main Arteries

From this north-south route the northern part of the proposed Central Artery will give an express road connection with the present Northern Artery via the Charles River Dam, and with the proposed Charles River Parkway via Charles Street, widened. From the intersection of Broadway and the proposed Blue Hills Radial an express road will extend via Castle Street and the proposed Boston & Albany Highway to Commonwealth Avenue at the Cottage Farm bridge. From the Blue Hills Radial at the Dover Street bridge there will be an express road connection with the Old Colony Parkway. The proposed Blue Hills Radial will cross the proposed Roxbury Crosstown express road, which will extend from the Old Colony Parkway at a point north of Savin Hill to the Charles River at Ashby Street. From the proposed Canterbury Parkway near Clarendon Hills there will be an express road connection with Washington Street and the West Roxbury Parkway via the proposed Clarendon Hills Parkway. The proposed Neponset River Parkway will connect this north-south route with the Southern Artery and the southerly terminus of the Old Colony Parkway.

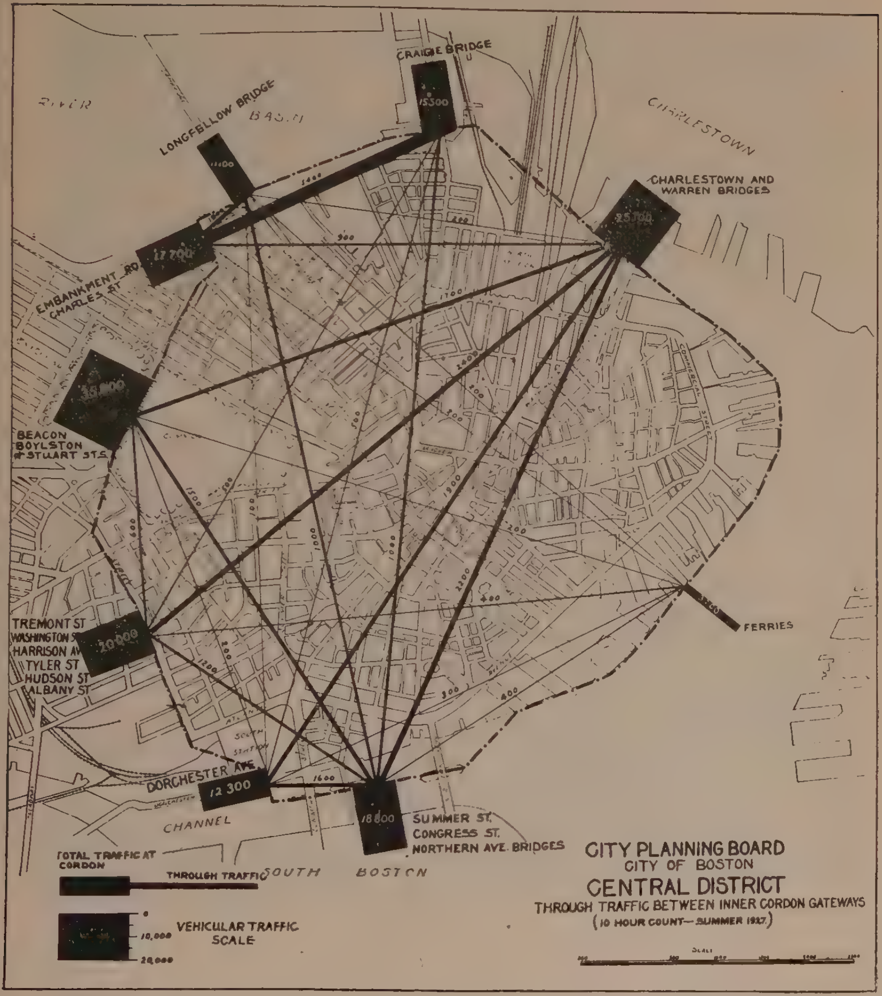


FIG. 4. — SHOWING THROUGH TRAFFIC PASSING BETWEEN THE INNER CORDON GATEWAYS

Of the 25,100 vehicles crossing the Charlestown and Warren bridges, 9,300, or 37 per cent, have neither an origin nor a destination within the Central District. Of this 37 per cent, 2,200 proceed across Central Boston to the South Boston bridges and 4,300 to Park Square, the South End and other points to the south

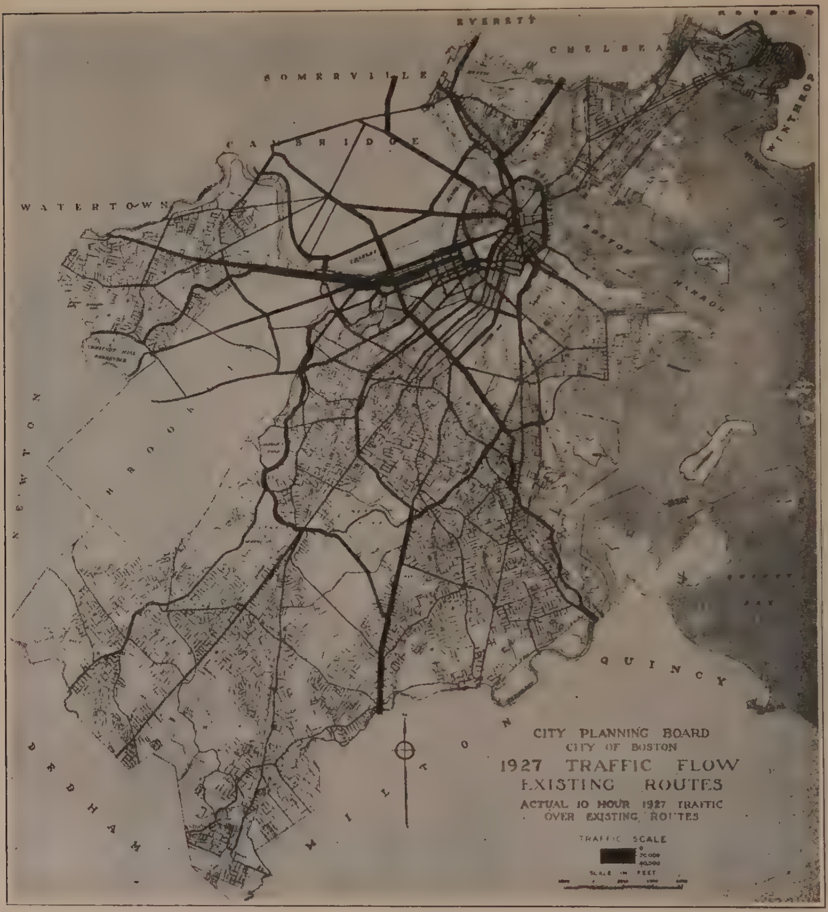


FIG. 5. — 1927 TRAFFIC FLOW OVER EXISTING ROUTES

The black lines along the major traffic routes are drawn to show the actual volume and distribution of traffic in 1927. The black lines are drawn to scale to show by their width the number of vehicles. At the scale of this reduction a black line one-twentieth of an inch in width indicates a traffic volume of 20,000 vehicles during a ten-hour period. Note the congestion at Governor Square and in Central Boston. Note the large volume of traffic over the Charles River Dam, with no adequate outlet toward Central Boston. Note, also, the apparent lack of a good traffic route into the heart of the city from Blue Hill Avenue

Central Artery — Upper Level Roadway

An important feature of the Central Artery and its southerly extension via the Blue Hills Radial will be an upper level roadway or viaduct extending from the North Station at Nashua Street to the Dover Street bridge, a distance of about two miles (see Fig. 2). This six-lane viaduct will have a capacity of 60,000 vehicles a day, traveling at an average speed of thirty miles an hour. It will by-pass the chief centers of congestion and will attract to itself approximately 40 per cent of the vehicles that are now clogging the surface streets of the central area (see Fig. 4). It will pass over Haymarket Square, over the congested surface traffic of the market district, and over all cross streets, including Congress, Federal, Summer, Essex and Kneeland. A two-level street of this kind will have from four to six times the capacity of an ordinary city street.

The Boston Metropolitan District extends as a three-quarter circle having a radius of about fifteen miles from the State House. The missing quadrant of the circle is occupied by the harbor and bay. It is this peculiar three-quarter circle pattern that creates one of Boston's chief traffic problems. To get from the North Shore communities on the northeast to the South Shore communities on the southeast one must either go by boat, travel many miles out of the way by skirting the city on the west, or push through the congested center. The Central Artery with its upper level roadway is a practical way to provide for this through traffic while at the same time affording enormous relief to the traffic going to and from the central district itself.

Design for Main Trunk Highways

The principle underlying the design of main trunk highways and parkways in the proposed Thoroughfare Plan is that they should provide, in so far as it is economically feasible, for a free and continuous movement of traffic. This requires that roadway levels should be separated at the more important intersections. On the proposed Central Artery there will be a central viaduct carrying over all cross streets. On the proposed parkways provision is made for overpasses or underpasses at all important intersections. For the Blue Hills Radial, the Roxbury Crosstown and other major routes a type of broad express road is recommended. For the locations selected this type of express road is believed to be the most economical and efficient means of providing the required traffic capacity, due consideration being given to the importance of speed, safety and comfort of travel.

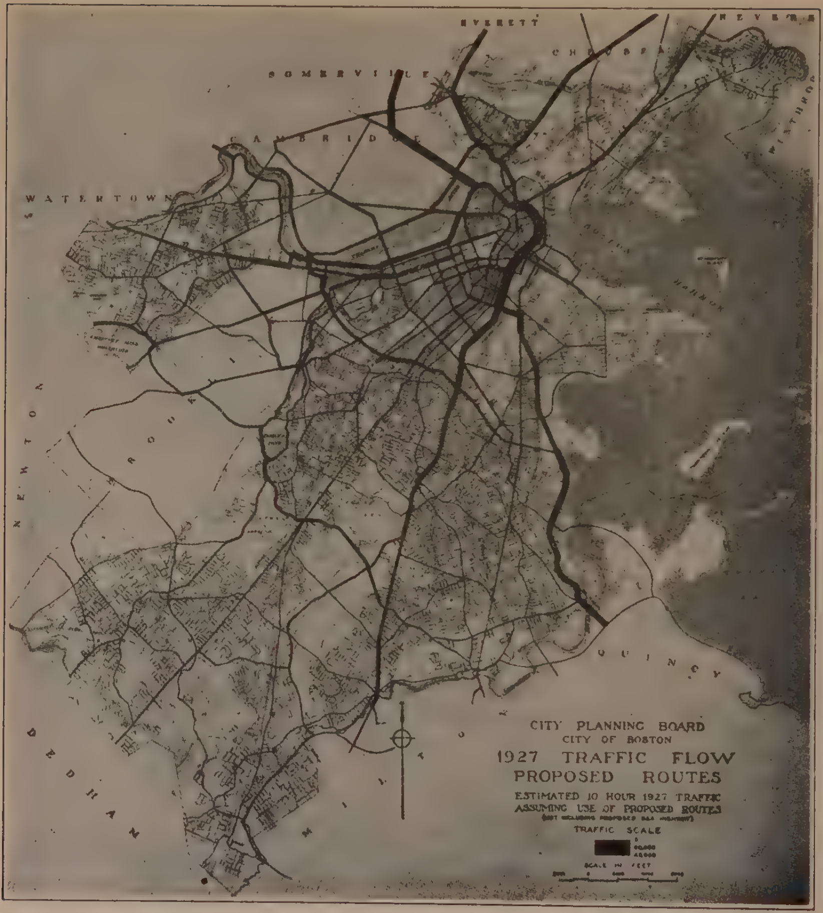


FIG. 6.—ESTIMATED DISTRIBUTION OF 1927 TRAFFIC USING BOTH EXISTING AND PROPOSED ROUTES

Note the clearing up of congestion shown in Fig. 5 at Governor Square and in Central Boston. Note the importance of the Central Artery, with its upper level roadway serving as a great interceptor to collect traffic and bypass it around the existing centers of congestion. Note, also, the importance of the Blue Hills Radial, serving as a southerly gateway to the Central Artery

The problem presented is both that of providing relief for existing congestion and of providing traffic capacity for approximately double the number of vehicles that now use the city's streets. One way to meet this problem would be to widen a large number of existing streets from their present widths of 50 or 60 feet to 80 or 100 feet. Such wholesale widenings would be enormously expensive and would not remove the chief source of congestion and delay which results from the crossings at grade. Under the conditions disclosed as the result of a careful analysis of the Boston traffic problem the construction of a few broad express roads seemed to be the only logical and practical solution.

Cross Section of Express Road

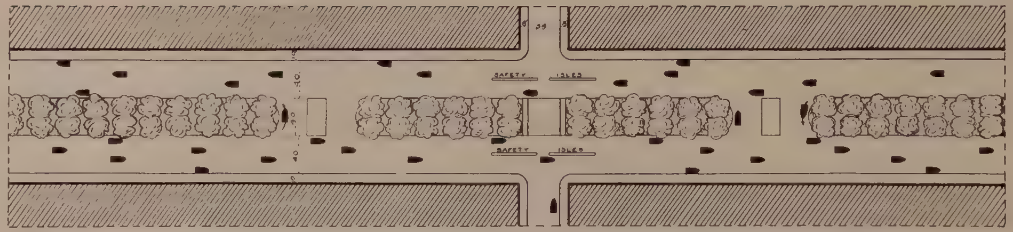
The typical section of the express road is 140 feet in width. It has two 10-foot sidewalks, two 40-foot roadways, and a central planting strip 40 feet in width. The two 40-foot roadways give six 10-foot traffic lanes for free moving traffic (that is, width for three vehicles moving abreast on each roadway) and a 10-foot space adjacent to each sidewalk for stopping and for access to abutting property. Each traffic lane should be marked by a white line on the pavement (see Fig. 7).

The 40-foot central planting strip is just as essential as the roadways themselves. It permits the traffic from minor cross streets to weave across without stopping the through traffic of the express road. An automobile coming from a side street turns to the right, weaves diagonally across the lanes of moving vehicles, turns left in a half-circle across the planting strip, enters the other roadway, weaves across the lanes of moving traffic and turns out to the right.

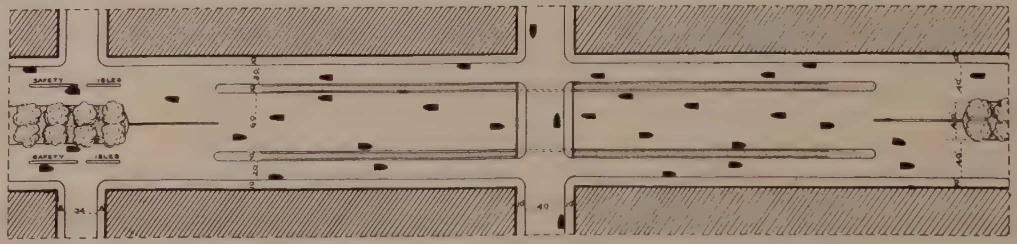
The vehicle coming in from the side street will have to weave diagonally across three lanes of fast moving vehicles. For this purpose a roadway length of at least 150 feet between point of entering and leaving is desirable. This is based on an allowance of 50 feet per lane of moving vehicles crossed. Where traffic is heavy this allowance should be increased to 80 feet per lane, or a total of 240 feet. It is believed that weaving is practical until the density on the through lanes exceeds 1,200 vehicles per hour.

Typical Traffic Circles

Fig. 8 shows at the left a typical arrangement for a traffic circle at a four-point intersection; and at the right a five-point intersection. The inner circle radius for the four-point intersection is 74 feet and for the five-point intersection 96 feet. The greater radius in the case



THE TYPICAL EXPRESS ROAD SECTION 140 FEET IN WIDTH HAS TWO 40 FOOT ONE DIRECTION ROADWAYS AND A 40 FOOT CENTRAL RESERVE STRIP



THE TYPICAL EXPRESS ROAD UNDERPASS HAS A 60 FOOT CENTRAL ROADWAY AND TWO 20 FOOT SIDE ROADWAYS

CITY PLANNING BOARD, CITY OF BOSTON

Fig. 7. — Typical Section of Express Road

of the five-point intersection is necessary so as to maintain, measured along the center line of the circular roadway, a minimum distance between the entering streets, center to center. This distance between entering streets is maintained at approximately 150 feet so as to provide adequate space for weaving.

The 48-foot circular roadways provide for four 12-foot lanes for one-way movement. The 12-foot unit is used in place of the normal 10-foot unit, so as to allow for the overhang of the body of the turning vehicle, and so as to give greater freedom for weaving.

A traffic circle is seldom as satisfactory as a grade separation. It is justified when the traffic is not heavy enough to warrant the greater expense of an underpass or overpass, or where for some reason grade separation is not practicable.

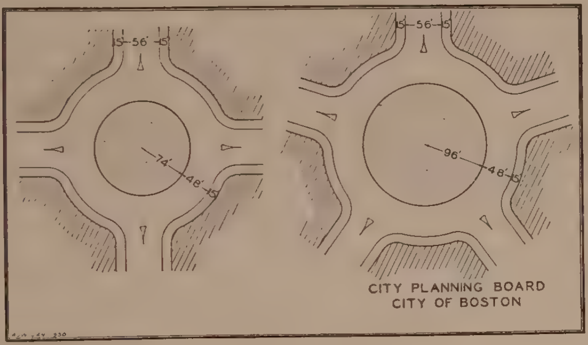


FIG. 8. — TRAFFIC CIRCLES

A prime essential for the success of a traffic circle is sufficient distance between entering streets to give vehicles an opportunity to weave. If adjacent streets enter the circle at an acute angle with each other vehicles are compelled to cross at right angles; there is no opportunity for weaving, and consequently the reason for the traffic circle — that of securing a continuous flow of traffic — fails.

The proposed traffic circle and underpass at the Charles River Dam illustrates certain advantages and limitations, both of the traffic circle and of the underpass. In this location a traffic circle alone would fail because inbound traffic from the dam turning left into Nashua Street would cross practically at right angles traffic going from Nashua Street into Charles Street. This conflict is avoided by an underpass for through Nashua-Charles traffic. On the other hand, the underpass without the traffic circle would fail because of the conflict between the heavy lines of traffic turning left to and from the bridge.

The proposed upper level traffic circle in the Central Artery at Haymarket Square is necessary so as to permit a daily total of 20,000 vehicles to and from the Charlestown and Warren bridges to enter the upper level roadway without stopping the flow of through traffic on that roadway.

DISCUSSION

QUESTION. I would like to ask if any provision has been made for pedestrians. Will it be necessary to underpass the intersections on the express highways?

MR. WHITTEN. At the vehicular overpasses and underpasses the pedestrian is well taken care of. If at any one point along an express road the number of pedestrians becomes very great, stop and go signals will have to be installed, or a pedestrian subway or overpass constructed. I think for a considerable period of time at most crossings the traffic will not be heavy enough to prevent pedestrians from crossing without undue danger. Probably even at the rush hour there will not be more than 600 cars per traffic lane, and that will give a considerable spacing between vehicles.

QUESTION. Is the central reservation for future development or for the present?

MR. WHITTEN. I think the 40-foot central reservation will never be needed for roadway purposes. Three lanes for moving cars are about as much as will be needed in any case. At some future time we may need to provide underpasses or overpasses to take care of cross traffic. In that case the central reservation will be used for that purpose. The 40-foot width gives just the minimum turning radius for a car to turn around the end. Less width than this would require a turning vehicle to go out into the second traffic lane.

QUESTION. I would like to ask Mr. Whitten if the upper level of the double roadway is intended to take truck and bus traffic as well as pleasure vehicles?

MR. WHITTEN. The present thought is that it will take all pneumatic tired vehicles. In New York City the West Side express highway takes only passenger automobiles. I think commercial vehicles with pneumatic tires should be permitted. It may be possible to make the upper level so noiseless that even heavy, hard-tired trucks might be permitted.

Mr. Lewis E. Moore. It would seem, offhand, that unless the upper level were used for trucks most of the saving would disappear, because very few passenger cars suffer real loss of money through delay.

Question. Has any attempt been made to separate traffic going in the same direction? Will trucks be given a definite lane?

Mr. Whitten. There will be segregation only as between the fast and slow moving vehicles. Slow moving vehicles will be required to keep to the right.

Question. In respect to ramps at the cross streets, is it more desirable to have the foot of the ramp at a distance from the cross street? Would there not be danger of accidents if it were made near the cross street?

Mr. Whitten. We try to get a short distance between cross streets and the entrance to the ramp, but that is not always possible. The streets are so near together. In the block between Congress and Federal streets it is possible because that is a long block.

Question. As the elevated structure has been brought into the matter I would like to know what provision has been made for abolishing the structure on Beach Street; or will the Central Artery cross it either above or below?

Mr. Whitten. The upper level roadway of the Central Artery will come down to the surface at Beach Street. Beach Street traffic will be prevented from crossing the Central Artery at this point.

Question. I would like to ask what the grade of the ramp is.

Mr. Whitten. We have tried to get a 5 per cent grade as a maximum.

Question. What plans have been made for additional parking in the city in the congested area?

Mr. Whitten. No plans have been developed, but it should be feasible to construct parking garages near the ramps or approaches to the upper level of the Central Artery. People could park their cars and walk to business or shopping close by.

Mr. Lewis E. Moore. Are there any further questions? If not, Mr. Fay is a member of the Society and is not eligible to a vote of thanks, but Mr. Whitten is not a member, and I suggest that we give Mr. Whitten a rising vote of thanks for coming here and giving his talk.

PILES AND PILE FOUNDATIONS

By J. Stuart Crandall *

(Presented at a meeting of the Designers Section of the Boston Society of Civil Engineers on March 10 1931)

Engineering structures are carefully analyzed and designed on the assumption that the foundations are adequate, stable and uniform in settlement. If the foundations do not meet these requirements, then the assumption is false, and much of the time and care taken in superstructure design is wasted. It is therefore important that as much attention be given to the analysis of the foundations as to the superstructure in order that the design of the latter may be based on logical premises as to the foundation. The profession in this country owes a great debt to Dr. Terzaghi for having aroused interest and instigated research in this important subject.

A large proportion of foundations consists of piles in groups driven in different kinds of soils. Those driven to rock or hardpan act as columns, and are usually treated as such, the bearing capacity being based on the end area in contact. Such pile foundations need little discussion. Others are driven in sands, gravels, clays, mud, etc., to some resistance usually determined by a pile-driving formula, which in this country and England is frequently the Engineering News formula, and in Holland, France and Belgium is usually the Dutch formula. It is the purpose of this paper to analyze the resistance of such piles, to show the derivation of and assumptions made in different formulæ, and to demonstrate the difference between the results of single piles and group piles. Little of this is original, being largely based on the work of Dr. Terzaghi,† Alfred Hiley‡ of England, and Noë and Trock,§ two Belgian engineers.

Pile-Driving Formulæ

The term "pile-driving formulæ" refers to formulæ based on the energy of blow and penetration of the pile. Such are "dynamic" formulæ. An *exact* formula of this type can only give the resistance of the pile to rapid penetration, while what is desired is the static bearing capacity. It follows, then, that a driving formula is of value only in such cases as the dynamic resistance (rapid penetration) is some measure of the static bearing capacity (slow penetration). In the usual sands, gravels and other relatively permeable, cohesionless soils the resistance to rapid and to slow penetration is about the same. In such cases a dynamic formula may give a close approximation of the static resistance of an individual pile. In clays, silts and relatively impermeable, cohesive soils there is no known relation between the dynamic resistance and static bearing capacity of piles, so that for such soils a pile-driving formula cannot give comparable results. The action of piles in these latter soils will be explained later.

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* The Crandall Engineering Company, 134 Main Street, Cambridge, Mass.

† "Erdbaumechanik."

‡ "Pile-Driving Calculations." The Structural Engineer, London, Vol. VIII, July and August, 1930.

§ "Pieux et Sonnettes."

Consider the relation between the energy of the hammer at the moment of impact and the work done in driving a pile, using the following nomenclature:

R_d = dynamic resistance.
R_a = allowable load.
W = weight of hammer striking parts.
W_p = weight of pile.
h = height of fall of hammer.
s = penetration of pile per blow.
E = modulus of elasticity of pile.
A = cross-sectional area of pile.
L = length of pile.
n = Newton's coefficient or coefficient of restitution.
C_1 = elastic compression of pile.
C_2 = rebound of pile due to elasticity of soil.
C_3 = elastic compression of driving cap.
C = rebound of pile.
e = efficiency of hammer:
    = 0.75 for usual drop hammer.
    = 0.90 for steam hammer.

Of the energy of the hammer at the moment of impact, only part is available to do the useful work of driving the pile. The rest of the energy is lost in impact, and in elastic compression of the pile, soil and driving cap, or follower, if one is used.

eWh = available energy at instant before impact.

$eWh\,\dfrac{W_p(1-n^2)}{W+W_p}$ = energy lost in impact.

$\frac{1}{2}R_d\dfrac{R_dL}{EA}=\frac{1}{2}R_dC_1$ = energy lost in elastic compression of pile.

$\frac{1}{2}R_dC_2$ = energy lost in elastic compression of soil.
$\frac{1}{2}R_dC_3$ = energy lost in elastic compression of driving cap.
$\frac{1}{2}R_dC=\frac{1}{2}R_d(C_1+C_2+C_3)$ = total energy loss due to compression.
R_ds = useful work done in driving pile.

If it be assumed for the present that there is no energy loss due to elastic compression of soil or of driving cap, then $\frac{1}{2}R_lC = \frac{1}{2}R_lC_1 = \frac{1}{2}\frac{R_d^2L}{EA}$, and the following equation written —

$$R_ds = eWh - eWh\frac{W_p(1-n^2)}{W+W_p} - \frac{1}{2}\frac{R_d^2L}{EA} \qquad (1)$$

Assuming the hammer 100 per cent efficient, $e=1.0$, and solving for R_d —

$$R_d = \frac{AE}{L}\left[-s+\sqrt{s^2+2Wh\frac{L}{EA}\,\frac{W+n^2W_p}{W+W_p}}\right] \qquad (2)$$

In case of perfectly inelastic impact, $n=0$, then equation (2) becomes Redtenbacher's formula —

$$R_d = \frac{AE}{L}\left[-s+\sqrt{s^2+\frac{2W^2h}{E(W+W_p)}\times\frac{L}{A}}\right] \qquad (3)$$

Now, if the impact be considered perfectly elastic, $n=1$ (which is never true), and the pile be considered as supported entirely by friction, the energy loss in compressing the pile becomes $\frac{1}{4}\frac{R_d^2L}{EA}$; then equation (2) becomes —

$$R_d = \frac{2AEs}{L}\left[\sqrt{1+\frac{WhL}{s^2EA}}-1\right] \qquad (4)$$

Rankine's Formula

Again, assuming that there is no loss due to compression, $C=0$; that the impact is inelastic, $n=0$; and that the hammer is 100 per cent efficient, $e=1.0$ —

$$R_ds = Wh - Wh\frac{W_p}{W+W_p}$$

$$R_d = \frac{Wh}{s}\times\frac{W}{W+W_p} \qquad (5)$$

Dutch formula

This formula is used a great deal in Holland, Belgium and France. Note that when $s=0$, $R_d=\infty$, which is obviously false and indicates that for small penetration per blow the results are too high.

If all of the energy losses be considered, the equation of work done in driving the pile is —

$$R_ds = eWh - eWh\frac{W_p(1-n^2)}{W+W_p} - \frac{1}{2}R_dC \qquad (6)$$

and

$$R_d=\frac{eWh}{s+\frac{1}{2}C}\times\frac{W+n^2W_p}{W+W_p} \qquad (7)$$

Hiley's formula

The following values for n are given by several authorities.

TABLE 1. — VALUES OF "N"

Cast iron on steel	0.55–0.60
Cast iron on concrete	0.4
Cast iron on wood	0.20–0.25

As n appears in the formula squared, it may be assumed that $n=0$, except possibly in the case of steel piles. Making this assumption, equation (7), measuring drop in feet and penetration in inches with a factor of safety of 6, gives —

$$R_a=\frac{2\,eWh}{s+\frac{1}{2}C}\times\frac{W}{W+W_p} \qquad (8)$$

This formula is suggested as a good one to use, for the reason that it is logically derived and will give consistent values for the *driving resistance.* The factor C is the measurement of the rebound of the head of pile and of cap, if one is used. Actual measurements to determine these values were made on piles by Hiley and Ackerman in England. Similar measurements were made by Goodrich * in this country. Hiley gives the following values for hard driving:

TABLE 2. — TYPICAL VALUES OF C, IN INCHES, HARD DRIVING

	LENGTH OF PILE (FEET).					
	10	20	30	40	50	60
Wood pile	0.37	0.49	0.61	0.73	0.85	0.97
Concrete with short cushion	0.27	0.36	0.45	0.54	0.63	0.72
Concrete with driving cap	0.57	0.65	0.74	0.83	0.92	1.01

Another method of determining the value of C will be explained farther on.

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* "The Supporting Power of Piles." Transactions, A. S. C. E., Vol. XLVIII, 1902.

If it be assumed in formula (7) that the impact is perfectly elastic, $n=1$, and that $\frac{1}{2}C=k$, and hammer 100 per cent efficient, $e=1.0$—

$$R_a=\frac{2Wh}{s+k} \qquad (9)$$

Engineering News Formula

the value of k being considered a constant of 1.0 for drop hammers and 0.1 for steam. When it is considered that the driving resistance is the same with both types of hammers, and comparing them with one-half the values of C in Table 2, which vary, as they should with the type, area and length of pile as well as the driving resistance, then it is evident that k should not be a constant. The result of the use of the values 1.0 and 0.1 is that, for small penetrations per blow, the Engineering News drop hammer formula usually gives results which are too low, and the steam hammer formula results which are too high.

The assumption that the impact is perfectly elastic is to neglect an important loss of energy. The impact is never perfectly *elastic*, as indicated by Table 1. It will be found more frequently to be perfectly *inelastic*, $n=0$, and the impact loss factor would be $\frac{W}{W+W_p}$. In the case of hammer and pile of the same weight this impact loss factor is 50 per cent. The absence of logic in these assumptions is evident and seems to explain the inconsistency of the results.

A recent study was made of some piles driven in sand at Ostende, Belgium, to determine their probable bearing value, it being proposed to build a structure which would cause a load of 50,000 kilograms per pile. Formula (2) was used with $n=0.5$ and a factor of safety of 6. The results are shown in Table 3 in comparison with those obtained with the Dutch Formula and the Engineering News Formulæ.

TABLE 3. — COMPARISON OF ALLOWABLE LOADS

[Factor of safety = 6]

NUMBER	Length (Meters)	Formula (2) (Kilograms)	Dutch Formula (5) (Kilograms)	ENGINEERING NEWS FORMULÆ	
				Drop Hammer (Kilograms)	Steam Hammer (Kilograms)
1	9	14,700	21,800	4,800	29,000
2	9	12,100	13,300	4,600	23,000
3	8	12,000	12,100	4,600	22,000
4	9	12,900	15,000	4,700	22,000
5	15	24,100	200,000	14,400	120,000
6	9	20,600	79,000	7,100	56,000
7	8	20,300	67,000	7,100	55,000

In this case a manually operated steam hammer was used with a low height of fall, causing small penetrations per blow, these penetrations for piles 5, 6 and 7 being much less than for the others. The results using formula (2) are consistent, although a little higher and not so correct as would be given by Hiley's formula, using $n=0$, or by equation (8). The results of the other formulæ are not consistent and corroborate the statements that for small penetrations the Dutch Formula and the Engineering News steam hammer formula give values too high, and the Engineering News drop hammer formula values which are too low. Needless to say, it was decided not to use the piles in this case.

Taking equation (6) and solving for h, gives —

$$h=\frac{R_d s+\frac{1}{2}R_d C}{eW}\times\frac{W+W_p}{W+n^2W_p} \qquad (10)$$

It is apparent that for any given case there is a maximum height of fall of hammer, h_0, below which there is no penetration of pile, $s=0$.

$$\text{When } s=0 \quad h=h_0=\frac{\frac{1}{2}R_d C}{eW}\times\frac{W+W_p}{W+n^2W_p} \qquad (11)$$

Substituting in equation (10) —

$$h=\frac{R_d s}{eW}\times\frac{W+W_p}{W+n^2W_p}+h_0 \qquad (12)$$

Solving for R_d —

$$R_d=\frac{eW\,(h\text{-}h_0)}{s}\times\frac{W+n^2W_p}{W+W_p} \qquad (13)$$

Assuming perfectly inelastic impact, $n=0$ —

$$R_d=\frac{eW\,(h\text{-}h_0)}{s}\times\frac{W}{W+W_p} \qquad (14)$$

with drop measured in feet, penetration in inches, and a factor of safety of 6, this becomes —

$$R_a=\frac{2\,eW\,(h\text{-}h_0)}{s}\times\frac{W}{W+W_p} \qquad (15)$$

Suggested formula

For a given dynamic resistance the equation for h_0 (11) is a straight line function, and the value of h_0 may be readily determined experimentally in the field. Measuring the penetration for several blows at three different heights of drop and plotting (Fig. 1) the penetration as abscissæ, the drop as ordinates, and drawing a line through them, the intersection with the Y-axis gives the value of h_0. If the points do not lie in a straight line there has been a change of resistance and the test should be repeated. Note that the value of h_0 varies with the weight of striking parts of the hammer, the type, weight, area and length of pile, so that h_0 should be determined whenever there is a marked change in these factors. Note, also, that h_0 varies with the square of the dynamic resistance and so should be determined when near its ultimate penetration or probable desired resistance.

The value of h_0 was determined in driving concrete piles at Boulogne s/Mer, France. The piles were about 16 inches square and 40 feet long. A square driving cap of azobé was used, the driving being done with a manually operated steam hammer, the striking parts of which weighed 7 metric tons and dropped 30 centimeters. The value in this case for h_0 was 15 centimeters.

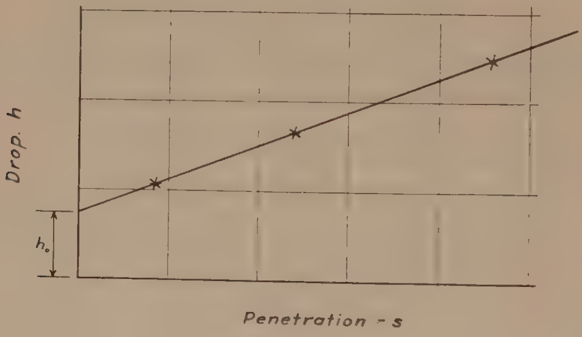

FIG. 1.—GRAPHIC DETERMINATION OF h_0

Similar determinations were made at Quebec with wood piles 25 feet long driven into sand with a 2,900 pound drop hammer. Here h_0 was found to be between 4 and 6 feet.

From determined values of h_0 it is possible to derive the values of C for future reference. Equating the terms for R_a in equation (15) and in equation (8), and solving for C, gives

$$C = \frac{2h_0 s}{h - h_0} \qquad (16)$$

PILES IN SILT, CLAY, ETC.

As stated previously, a dynamic formula is not applicable to piles driven in clays, silts and other such cohesive, impermeable soils. Consider the conditions when piles are driven into such soils, bearing in mind that for short periods of time these soils are practically incompressible, while over long periods of time they are very compressible (Fig. 2).

While a pile is being driven, water is squeezed out of the soil, forming a slimy mud which lubricates the sides and thus reduces the friction to a small value. The resistance of the pile is then due largely to that of the point where the pressure is high. The point causes the soil to displace and push up along the surface. Measurements indicate that the amount of soil displacement at the surface is equal to the volume of the pile in the ground. The driving resistance is about the same for small and large penetrations.

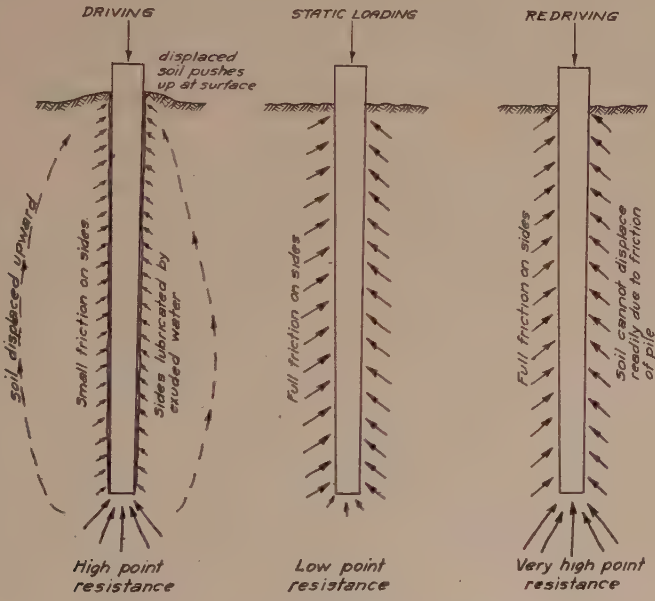

FIG. 2. — PILES IN SILT, CLAY, ETC.

After the pile has set for a time, the excess water is reabsorbed by the soil, by the pile, or both, causing the soil to "grip" the pile. When the pile is loaded there is, therefore, full friction along the sides and small point resistance. Tests indicate that the point resistance is 15 to 20 per cent of the total static bearing capacity. It is evident, due to the different elements which make up the driving resistance and the static resistance, that the driving resistance as determined from a pile-driving formula is not the same as the static bearing capacity. For short piles the driving resistance may be the greater, and for long piles it may be much smaller.

It is sometimes advocated that the allowable load be the resistance determined by a pile-driving formula after the pile has set for some time. At the time of redriving there is full friction along the sides of the pile. The soil under the point cannot readily displace upward, being held by the friction along the pile, thus causing high point resistance. The resistance to redriving is, therefore, equal to the full frictional resistance plus high point resistance. It may be several times the static resistance.

It is evident that neither the driving resistance nor that found in redriving, as determined by a pile-driving formula, can give any measure of the load a pile can carry. A reasonable rule to follow is that a pile-driving formula should not be used in cases where the resistance to redriving is found to be much greater than the driving resistance. In such cases, what procedure should be followed?

Loading tests will give the bearing capacity of individual piles, but such tests should be continued to *failure* to assure the choice of an allowable load with a known factor of safety. Tests made on piles by the Whangpoo Conservancy Board in Shanghai, by French engineers in Tunis, and on model piles by Ackerman in England, show that in clays and silts the frictional resistance per unit of pile surface in contact is practically the same, irrespective of the depth in the soil. (At Shanghai tests actually indicated somewhat smaller values for the greater depths.) This means practically uniform horizontal principal stress, which cannot be due to the soil overburden.

If the ultimate frictional resistance per unit area is known, the *bearing value of a single pile* may be readily calculated by multiplying the resistance by the area in contact, neglecting the point resistance, which is small. This is the method adopted at Shanghai. To obtain these friction values, it is necessary to test the pulling resistance and bearing capacity. There is little such information available. Table 4 gives friction values for soils in several localities:

TABLE 4. — FRICTIONAL RESISTANCE OF PILES IN SILTS, CLAYS, ETC.

LOCATION	SOIL	Penetration (Feet)	Contact Surface (Square Feet)	Ultimate Load (Pounds)	Friction per Square Foot (Pounds)	Source of Information
Aquia Creek, Va.	Fluid mud	45–50	117	13,333	95*	Eng. News, Feb. 23, 1893
New York, foot of 17th Street, North River	Mud	50	219	33,600	130*	Proceedings Int. Eng. Cont., St. Louis, 1904
Rhine Valley	Soft muck	0–35	–	–	130	Terzaghi
Rhine Valley	Soft clay	25–35	–	–	295	Terzaghi
Proctorsville, La.	Mud, sand, clay	35	144	62,500	370*	Eng. News, Feb. 23, 1893
Portland, Maine	Soft blue clay	14	58.5	50,000	740*	Fay, Spofford & Thorndike
Hull, England	Stiff blue clay	18	–	–	1,850	Terzaghi
Shanghai	Silty, microscopic sand	4–50	–	–	130 to 900	Terzaghi
Tunis	Soft muddy clay	100	–	200,000	370*	Le Genie Civil, Dec. 2, 1929

STATIC FORMULÆ

A number of formulæ have been derived for computing the static bearing capacity of piles. None has proved satisfactory. One of the most widely known of these is that derived by Benabenq,[†] an engineer of public works in French Indo-China, which takes the form

$$R = dl(m + nl)$$

d = weight of soil per m^3.
l = total penetration of pile in meters.
m and n = coefficients, depending on the nature of the pile and angle of repose of the soil.

This is based on Rankine's theory of conjugate stress, and on the assumption that the angle of repose and the angle of internal friction are the same. A complete set of tables was calculated for different values of the coefficients. However, the applicability of Rankine's theory is open to serious doubt, and it is now known that the angle of repose and the angle of friction may be far different. Dr. Dörr derived a modification of Benabenq's static formula, but with similar assumptions, so that its value is questionable.

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* Friction calculated after deducting 15% for point resistance.

[†] Le Genie Civil, January 27, 1912.

Both of these formulæ are based on the horizontal pressure against the pile caused by the weight of the soil overburden, and both neglect the effect of consolidation and capillary pressure in clays and silts. They usually give results which are too high.

Soil Loading Due to Individual and Group Piles

A single loaded pile transfers its load to the soil by friction along the sides, by point resistance, or both, creating stress in the soil. This stress may be calculated approximately along any plane using Strohschneider's modification of Boussenesq's analysis. Fig. 3 gives a curve for vertical stress distribution along the plane of the point for a pile of length L and load R supported entirely by friction. The maximum stress is $3.5\frac{R}{L^2}$, and most of the loaded area is within a circle of radius 0.6L.

With similar piles in a group, the result is quite different. When spaced closer than 1.2 times the length of the piles, there is a marked overlap of the zones of stress, the amount of this overlap increasing with the decrease in pile spacing. The effect of loading a group of twenty-five such friction piles spaced apart a distance equal to 0.2L is shown on Fig. 4. The dotted lines are the vertical stress curves for the individual piles indicating the overlapping. The full line is the combined curve of vertical stress under the center row of the group indicating a maximum stress of $15.4 \frac{R}{L^2}$ being 4.7 times that of the single pile. Were it possible to omit the piling and use a mat foundation, the vertical soil stress along this same plane would be $8.5\frac{R}{L^2}$, or only 55 per cent of that due to the pile group. The pile spacing shown is equivalent to 8 feet for piles 40 feet long. Were the spacing reduced by half, the maximum stress would be over twice that indicated.

It is evident that to reduce soil stress, fewer and longer piles should be used, the spacing increasing with the length of the piles and the length increasing with the total width of the foundation. A spacing rule used in Shanghai, where the piles are considered as supported entirely by friction, requires a minimum spacing of about 4 feet for a foundation 10 feet wide, and of about 11 feet for a foundation 100 feet wide.

These diagrams show that loading tests and pile-driving results of individual piles cannot give much indication of the stress and settlement of a group. The effect of the group as a whole must be analyzed, together with the physical properties of the soil. It is an error to assume that if a single pile can support a load of 15 tons with a given settlement, twenty such piles in a group would support 300 tons with the same settlement. The experience with "pretest" piles well demonstrates this fact.

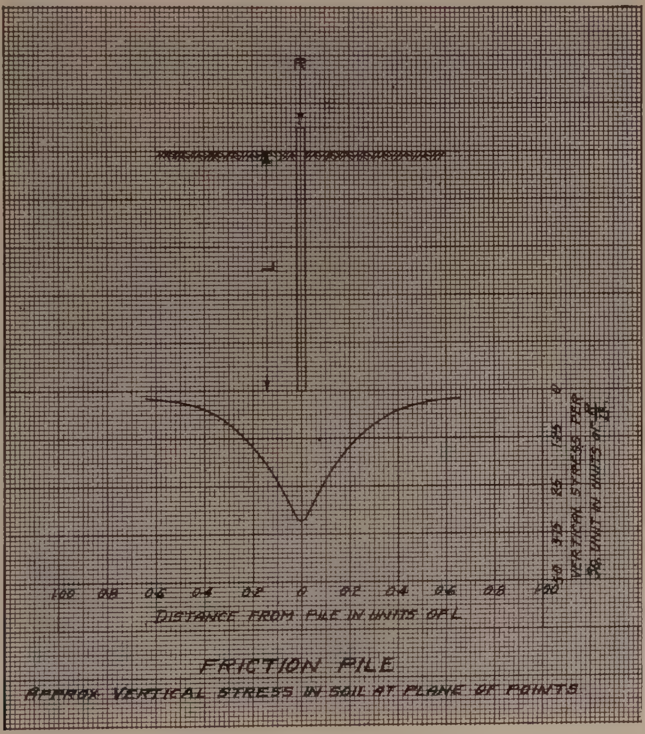

FIG. 3. — LOAD AT PLANE OF PILE POINT — INDIVIDUAL PILE

Pretest piles are pushed into the soil with hydraulic jacks until 50 per cent above the prescribed load is carried twenty-four hours without settlement. During the early development of this method some consternation was aroused, when, after such pretesting of the

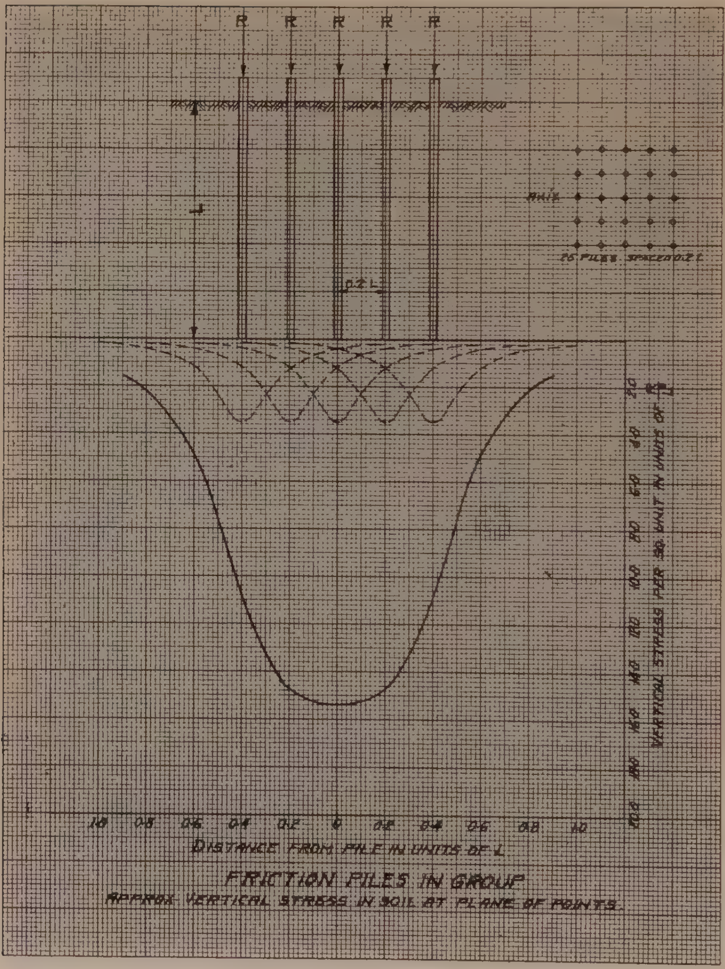

FIG. 4. — LOAD AT PLANE OF PILE POINTS — GROUP OF PILES

individual piles, structures supported on groups of piles settled appreciably. This resulted in modified practice. These piles are now jacked individually to 50 per cent above the specified load, and then groups of five or six piles are loaded by connecting the jacks together. There is usually additional settlement when the group is so loaded, this additional settlement being sometimes as much as two inches.

This paper has given a bare outline of the problems involved in pile foundations. A great deal is yet to be known. To advance our knowledge of this important subject, much further information must be compiled on pile-driving results, load tests, pulling tests, and experience with actual foundations. Lessons can be derived from the failure or excessive settlement of pile foundations, but such occurrences are not widely advertised.

In conclusion, the following points deserve emphasis:

1. When a pile-driving formula is used it should be one which can give logical and consistent values for the driving resistance.

2. In clays, silts, etc., a pile-driving formula gives no known measure of the static bearing capacity.

3. For piles in groups, loading tests and driving data of individual piles do not give results comparable for the group. The effect of the entire group should be analyzed.

OF GENERAL INTEREST

BOSTON SOCIETY OF CIVIL ENGINEERS' SCHOLARSHIP IN MEMORY OF THE LATE DESMOND FITZGERALD

Awarded to Raymond Edgar Edson, Student at Northeastern University

In accordance with a vote of the Board of Government of the Boston Society of Civil Engineers on February 18, 1931, there has been appropriated from the income of the Desmond FitzGerald Fund the sum of $100 as a scholarship for a student in Civil Engineering at Northeastern University. The presentation of this scholarship was made by Past President Lewis E. Moore on April 16, 1931, at a university assembly presided over by Dean Carl S. Ell of Northeastern University, at Jordan Hall.

The recipient was Raymond Edgar Edson, a senior student in the civil engineering curriculum of Northeastern University, a resident of Swampscott, Mass., and a graduate of Swampscott High School. He has proved himself a young man of sterling character during his four years at the University, and scholastically definitely better than the average student. In addition to being faithful to his studies and to his cooperative work he has been a leader in student activities. He has been a member of the Northeastern University Section of the Boston Society of Civil Engineers for the past two years, and during the past year has been a member of the Executive Committee of the Section. He has been president of his class for four years. He has been a member of the Student Council for three years and president for two years. He is vice-president of his fraternity and is editor-in-chief of this year's "Cauldron."

The FitzGerald Fund was established by a bequest from the late Desmond FitzGerald, a Past President and Honorary Member of the Society. The provisions of the gift were that the income should be used for charitable and educational purposes.

John Ripley Freeman, Past President of the Boston Society of Civil Engineers, honored at Providence, Rhode Island

A testimonial dinner was tendered to Mr. John R. Freeman at the Biltmore Hotel, Providence, Rhode Island, on Tuesday evening, April 21, 1931. More than 250 engineers and scientists were present to express their admiration of the accomplishments of this famous hydraulic engineer. Official representatives were present from the American Society of Civil Engineers, the American Society of Mechanical Engineers, the Providence Engineering Society and the Boston Society of Civil Engineers, together with many distinguished engineers and business men.

Those who spoke particularly of Mr. Freeman's achievements were the following: Frank E. Winsor, chief engineer of the Metropolitan District Water Supply Commission, a vice-president of the American Society of Civil Engineers, and a past president of the Boston Society of Civil Engineers; Blake R. Van Leer, assistant secretary of the American Engineering Council; Charles T. Main, past president of the American Society of Mechanical Engineers, and also past president of the Boston Society of Civil Engineers.

Greetings to Mr. Freeman were presented by Governor Norman S. Case of Rhode Island; United States Senator Felix Hebert of Rhode Island; Chester T. Morey, president of the Providence Engineering Society; Walter Humphreys, secretary of the corporation of the Massachusetts Institute of Technology, Mr. Freeman's alma mater; Harry E. Sawtell, president of the Boston Society of Civil Engineers; Prof. Charles F. Scott, of the American Engineering Council and the American Institute of Electrical Engineers; Benjamin G. Butolph of the Associated Factory Mutual Fire Insurance Companies; the Rev. John J. Lynch, S.J., of Fordham University, representing the Seismological Society of America; Prof. Charles W. Brown of Brown University, representing the Geological Society of America; Dr. Clarence A. Barbour, president of Brown University; E. H. Cameron, president of the Northeastern Section of the American Society of Civil Engineers; and George H. Finneran, president of the New England Water Works Association.

A silver platter was presented to Mr. Freeman as a mark of appreciation of his work, his ability as an engineer, and his quality as a man. The platter was inscribed as follows: "From the Providence Engineering Society and friends, as a testimonial to you that they may honor you for your lasting contribution to engineering and industry."

It is interesting also to note that this year marks the fiftieth anniversary of Mr. Freeman's joining the Boston Society of Civil Engineers, of which he was president in 1893 and in which he was elected an honorary member on September 17, 1917.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

April 15, 1931. — The regular meeting of the Boston Society of Civil Engineers was omitted on this date in order to join in a general meeting of the Engineering Societies of Boston.

A lecture with moving pictures was presented by Mr. V. R. Jacobs, assistant manager, Aeronautical Department, Goodyear Tire and Rubber Company, on the "Design and Construction of Lighter-than-Air Craft," with descriptions of the helium airships for the United States Navy.

An enjoyable feature for members of the Boston Society of Civil Engineers, prior to the general meeting, was the supper at which the families and friends of members were guests. The supper was served by Fitzpatrick Brothers, caterers.

Everett N. Hutchins, *Secretary.*

Sanitary Section

April 1, 1931. — At six p.m. 19 members and guests dined at Patten's Restaurant.

The meeting was called to order at 7.15 in the Societies' Library by the Chairman, with 34 members and guests present.

No unfinished or new business arising, the speaker of the evening was introduced, — Mr. Edward Wright, Chairman of the Massachusetts State Reclamation Board, who spoke on "Mosquito Control."

The speaker described the history of the State Reclamation Board, and of mosquito control work in Massachusetts. He described the work done in New Jersey, and more especially the work done in Massachusetts since 1929 and that which is in progress or planned for the immediate future.

Motion pictures of mosquito control work in New Jersey were shown.

Mr. Robert W. Wales, Entomologist of the Massachusetts State Reclamation Board, supplemented Mr. Wright's talk with detailed accounts of the Board's work, and of the habits of the various types of mosquitoes.

Among the guests present were Mr. H. A. Johnson and Dr. Bruce Mayne of the United States Public Health Service, who contributed to the discussion of the subject.

Mr. John Pierce described mosquito control and other sanitary work in Cuba.

A vote of thanks was extended the guest speakers.

Meeting adjourned at 9 p.m.

George G. Bogren, *Clerk.*

Designers Section

April 8, 1931. — The April meeting of the Designers Section was called to order in the Affiliation Rooms at 6.10 p.m. by Chairman Harsch.

The minutes of the previous meeting were read and accepted.

The speaker of the evening, Mr. Burtis Brown, was then introduced. He spoke on the subject of "Light Weight Floor and Roof Construction." His talk, illustrated with slides, covered the various kinds of floor joists and decking used in this type of construction. He explained the advantages, economies and limitations of the different systems.

Mr. Joseph B. Harriman then read a discussion of Mr. Brown's paper, showing cost comparisons of a large number of different types of floor construction.

The meeting was then opened to general discussion in which a large number of members and guests took part.

The meeting was adjourned at 8.25 p.m. There were 65 members and guests present.

Raymond A. Freeman, *Clerk.*

APPLICATIONS FOR MEMBERSHIP

[May, 20, 1931]

The By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

For Admission

Adams, Ralph, Arlington, Mass. (Age 30, b. Arlington, Mass.) Graduate of Dartmouth, 1923; attended Massachusetts Institute of Technology, 1924–26. Employed by the New York Central Railroad, and since September, 1927, with Fay, Spofford & Thorndike as assistant engineer. Refers to *C. A. Farwell, F. H. Fay, R. W. Horne, F. L. Lincoln, L. B. Turner.*

Jubb, Leonard Wainwright, Boston, Mass. (Age 23, b. Shirley, Mass.) Attended Wentworth Institute, 1925–27; Lowell Institute, 1928–30. With Stone & Webster Engineering Corporation, 1927–28; with Fay, Spofford & Thorndike, 1928 to date, as draftsman. Refers to *C. A. Farwell, F. H. Fay, R. W. Horne, F. L. Lincoln, L. B. Turner.*

McIntyre, Kenneth Eastman, Walpole, Mass. (Age 32, b. East Hardwick, Vt.) In the fall of 1922 entered the employ of Schuyler Clapp, C.E., and was with him until the fall of 1927, with the exception of six weeks with Fay, Spofford & Thorndike. In the fall of 1927 purchased the business of Mr. Clapp, and in August, 1930, was appointed assistant town engineer of Walpole, Mass., and carried on own business in conjunction with this until January 1, 1931, when he was appointed acting town engineer, and on March 20, 1931, was appointed superintendent of sewers as a new town engineer came in. To date is filling this position. Refers to *C. A. Farwell, R. W. Horne, C. B. Humphrey, H. L. White.*

O'Neill, Carroll C., Chestnut Hill, Mass. (Age 40, b. North Adams, Mass.) Educated in the Martin Grammar and English High schools of Boston, and in Tufts Engineering School. Experience: engineer with American Construction Company; construction engineer, Aberthaw Construction Company; construction engineer, Boston Army Base; licensed builder, classes A, B, C, city of Boston; at present, New England District engineer and manager, Union Fibre Company (refrigerating and insulating engineers). Refers to *T. R. Lyons, G. N. Perry, C. D. Proctor, L. J. St. Amand.*

ADDITIONS

Juniors

Richard Hubbard Hamill, 281 Western Avenue, Lynn, Mass.

Raymond Gustaf Rolin, 10 Verona Street, Lynn, Mass.

DEATH

Henry D. Woods . . . April 2, 1931

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FOUNDED 1848

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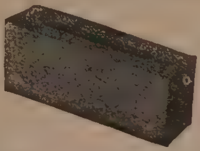

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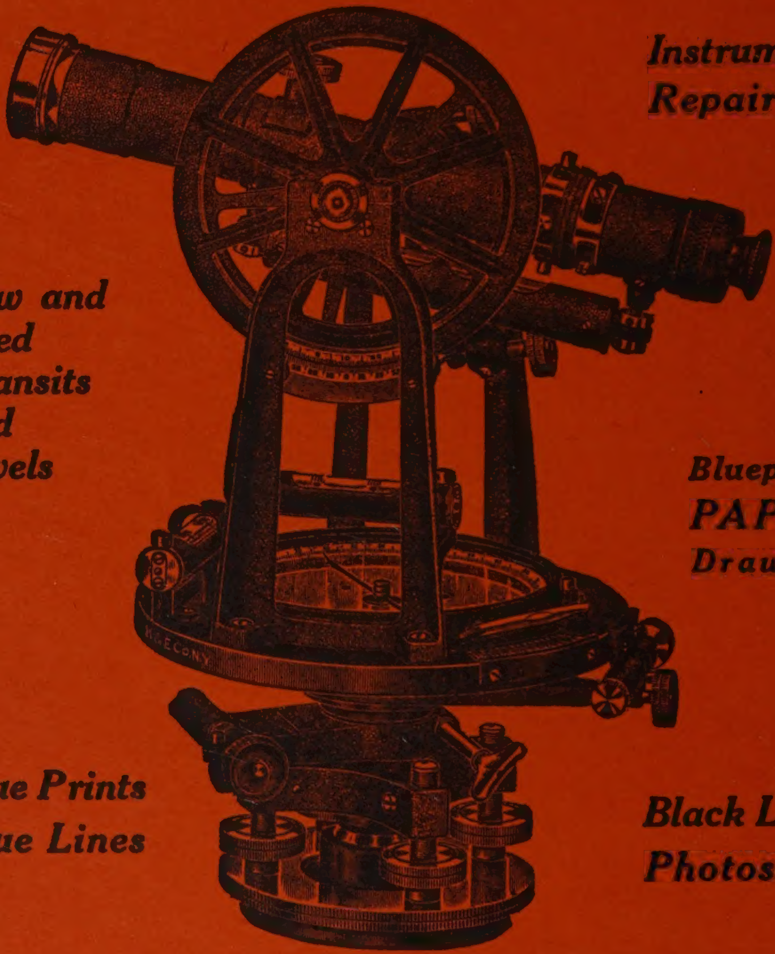

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